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AN EFFECT OF COBALT OXIDE NANO ADDITIVE WITH BIODIESEL BLENDS USING CIDI DIESEL ENGINE

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ABSTRACT

Major research is focused on fuel consumption and emission reduction in the past years. There is growing interest on alternative fuels due to volatile fossil fuel price and depletion. Utilization of transition metal additive in nanocrystalline form helps the combustion in molecular level and also reduces emissions and fuel consumption values. To forms a stable nano fluid metal oxide additive is added to biodiesel and ultrasonicated. The single cylinder, air cooled, and constant speed kirloskar engine is chosen for experimental study. The performance studies indicated the increase in thermal efficiency of 1% because the better mixing resulting secondary atomization and disruption of primary droplet containing additive and burns completely. Nearly 60% emission reduction was observed for 100% biodiesel at full load.

KEYWORDS: Biodiesel, Nanoparticle, Engine Characteristics, Alternative Energy & Jatropha Oil

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Original Article

INTRODUCTION

In recent days, research on Internal Combustion (I. C) engines for alternative fuels has been increasing due to increase in the environmental concerns and increase in the conventional fuels price. Biodiesel, it is processed from animal fats, vegetable oils, an alternative diesel fuel and so on. The advantages of biodiesel are improving exhaust emission profile of exhaust gas, oxygen content, sulphur-free; promote combustion process and high cetane number. Many researches have been conducted on bio-based fuels. Biodiesel is one of the fuels, which has commercial and industrial interest. The researches have shown that biodiesel-fuelled engines produce fewer amounts of un-burnt hydrocarbons, carbon monoxide, less particulate emissions and sulphur oxides compared to diesel fuel [1-3].

The additive is mixed with the fuel in molecular form. Nanoparticles won't make any clogging problem like micron sized particles and it possess higher surface area and resulting better catalytic activity [4, 5]. With the recent advances in the nano-science and nanotechnology, one can effectively utilize the fuel additive. Additive is to be added to the base fuel in order to enhance desirable chemical properties to modify the existing properties. In the present work, the cobalt oxide nano particle (~20 nm) is added to the jatropha biodiesel and performance and emission characteristics are investigated.

EXPERIMENTAL DETAILS

Preparation of Biodiesel

The acid esterification and pre-treatment for removing free fatty acid content in the oil, which could reduce the FFA in the presence of optimized methanol and catalyst. In the trans-esterification process, different types of oils, triglycerides react with alcohol (methanol/ethanol) to produce esters and glycerin. The catalyst is added to the reaction. Biodiesel consists of esters of fatty acids obtained from trans-esterification of vegetable oils posse’s properties similar to that of mineral diesel oil. The trains-esterification process is performed to reduce the viscosity of vegetable oil and hence to improve the properties of the flow. The reaction temperature, ratio of vegetable oil to alcohol, mixing intensity (RPM), amount of catalyst raw oils used and catalyst are the important parameters used in this process [7].

The direct alkali trans-esterification requires lower FFA, since higher FFA content oil is pre-treated and it is evolved to base catalysis using optimized amount of methanol and base catalyst. After the completion of the reaction, it forms two layers; Upper one is methyl ester and lower one is higher molecular weight glycerin.

Preparation of Cobalt Oxide Nanoparticle

There are many methods for the nano particles preparation, such as plasma arcing, sol-gel synthesis and ball milling process and so on. Several metals are known to catalyze combustion of hydrocarbon fuels. Among these methods, ball milling is a grinder, which reduces the grain size to the nano range. The catalyst significantly assists in combating vehicular emission in many countries. The cobalt nanocrystalline oxide powder is prepared by ball milling. The cylinder rotates at relatively slow speed, allowing the balls to pour through the base of the mill, thus dispersing or grinding the materials for longtime leads to the particles of nanometer size. The grinding is carried out within the cylinder by pounding and rolling of a ceramic balls or charge of steel. [4, 5].

Experimental Setup

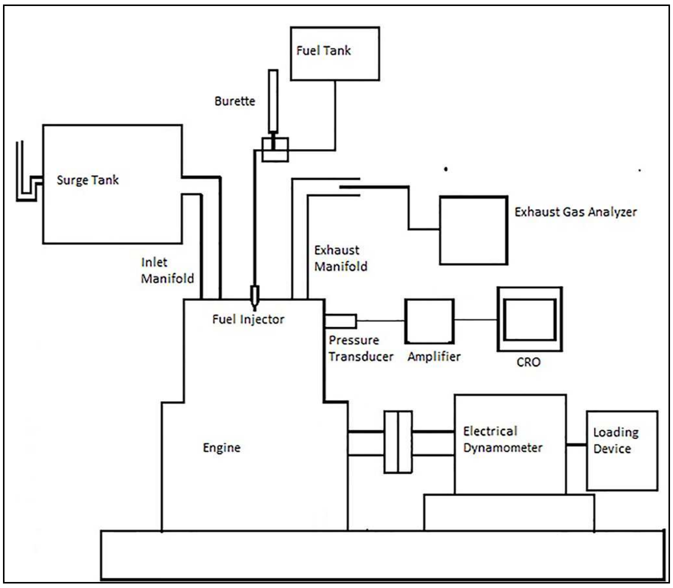

Figure 1: Schematic of Experimental Setup

The single cylinder 4-stroke naturally aspirated, air cooled diesel engine (Kirloskar TAF-1) having 4.4 kW power at 1500 rpm is used for our experimental investigation. The capacity of the engine cylinder is 661 CC; bore-stroke

dimension is 87.5 mm × 110 mm with the compression ratio of 17.5:1. The injection time is 23° bTDC with the pressure of 200 bars. Fuel flow rate is arranged with the use of burette. The engine is coupled to an electric dynamometer to apply the load. To measure the exhaust emissions the exhaust gas analyzer is used and with the help of piezoelectric transducer the pressure-crank angle diagram is obtained.

RESULTS AND DISCUSSIONS

The nano cobalt oxide powder of 100 mg and surfactant (CTAB) of 100 mg are mixed based on optimization process.

Adding cobalt oxide nano particle in various blends biodiesel 10%, biodiesel 20%, and biodiesel 100%, (namely B10, B20, and B100 respectively) and nano particles were dispersed using ultra-sonicator in order to reduce agglomeration. The additive generally reduces the ignition delay, improves the combustion by its catalytic effect, burns the carbon deposits and reduces the black smoke.

Brake Specific Energy Consumption

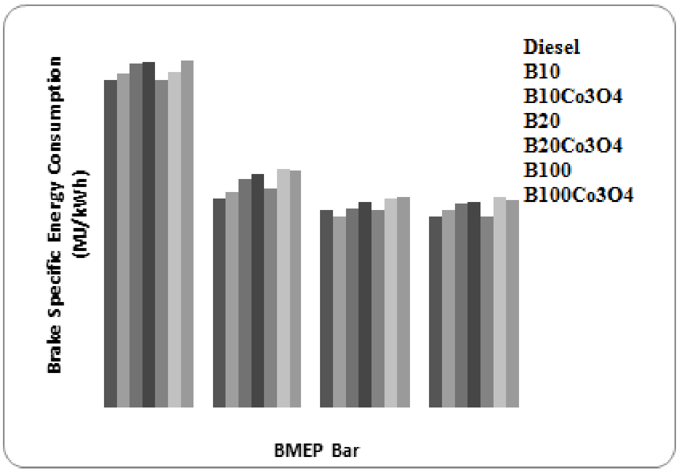

Figure 2: Variation of Brake Specific Energy Consumption with Break mean Effective Pressure

The variation of brake specific energy consumption (BSEC) for jatropha methyl ester blends were compared with diesel as shown in Figure 2. BSEC for biodiesel and its blends are higher compared to diesel. In order to obtain the same power output, more amount of fuel is to be supplied and hence higher fuel consumption is observed for biodiesel. This is due to the fact that biodiesel contains 10 to 11 % of oxygen content, resulting lower calorific value compared to diesel. Jindal et al**.** [13] investigated the comparison of methyl esters of Jatropha and Karanja oils in a diesel engine for combustion, performance and emission. BSEC was reduced by the addition of cobalt oxide additive. Average reductions in BSEC were 7.95% and 2.10% respectively, for B20-Co_3O_4 and B100-Co_3O_4 in the full load condition. The peak pressure is higher with diesel and the net rate of heat release is lower for JME and KME compared to diesel. This is due to the catalytic activity of cobalt oxide and helps to improve the combustion; hence the correct quantity of fuel would be utilized. The emission of HC, NOx and smoke denseness are found higher for diesel compared to biodiesel. The results showed that the karanja methyl ester (KME) have better thermal efficiency and specific fuel consumption (SFC) compared to jatropha methyl ester (JME).

Brake Thermal Efficiency

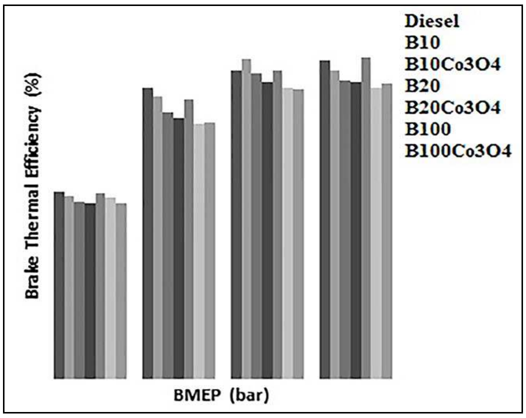

Figure 3: Variation of Brake Thermal Efficiency with Break Mean Effective Pressure

The variation of brake thermal efficiency (BTE) for biodiesel and its blends are compared with diesel and shown in Fig. 3. As the biodiesel proportion exceeds a certain limit, output power decreased. At 75% load condition, B10 shows 1% improvement in thermal efficiency compared to diesel. This is due to oxygen content possessed by the biodiesel, which improves the combustion. It is clear that improvement in combustion efficiency is unable to offset the power loss due to low heating value.

Figure 3 shows the brake thermal efficiency improvement for B20-Co_3O_4 (2.32%) and B100-Co_3O_4 (0.3%) due to the inclusion of additive in full load condition, which significantly reduce the evaporation time and hence improved the combustion. The experiments were carried out using jatropha biodiesel (JB100) (B0) and conventional diesel. The silver nano-particles were blended with Honge biodiesel called Honge Oil Methyl Ester (HOME) in the mass fractions of 25 ppm and 50 ppm using a mechanical homogenizer and ultrasonicator [9]. Sajith et al. [2] prepared **c**erium oxide (CeO_2) nanoparticle, used as an additive and it was found that it reduces the emission level of hydrocarbon and NOx appreciably and observed the maximum increase in thermal efficiency of 1%.

The substantial reduction in the harmful pollutants and considerable enhancement in brake thermal efficiency from the engine for the biodiesel blends with nano-additive was observed. Brake thermal efficiency was high for HOME+50 silver with reduced harmful pollutants compared to HOME+25 silver blends. The cerium oxide absorbs oxygen for the reduction of NOx or provides oxygen for the oxidation of CO and it acts as an oxygen donating catalyst. The performance and emission characteristics of polanga oil diesel fuel blend were investigated by internal combustion engine [10]. Between diesel and ethanol the phase separation is prevented using biodiesel prepared from the castor oil through transesterification process. It was observed that the presence of iron oxide nanoparticle, in diesel polanga oil reduces the ill effects. With polanga oil–diesel fuel blend, Iron oxide nanoparticles were doped as additive. Emission and performance characteristics of diesel engine were studied for 10%, 20% and 30% (weight %) polanga oil with diesel. Iron oxide nanoparticles attentiveness of 150 ppm and at 25% polanga oil blend with diesel, the engine performance was observed to be similar to that of running on neat diesel. It was found that the doping of iron oxide nanoparticle with Polanga oil-Diesel fuel could be the potential substitute for diesel in running CI engines.

Hydrocarbon

Figure 4 shows the hydrocarbon (HC) emission with the effect of nano particles for diesel, biodiesel and its blends. It is clearly observed that reduction in HC emission for all blends compared to diesel, because of higher oxygen content. Fuel-rich combustion, valve overlap, crevice flows, misfiring and flame quenching desorption of hydrocarbon causes HC emission. The increase in HC could also be due to the mixing of air and fuel and larger droplet size from higher fuel viscosity of biodiesel. By doping additive, it is possible to reduce the emission at full load conditions for all blends nearly 60% reduction was observed for B100 at full load, because the disruption of primary droplet containing additive resulting secondary atomization and the mixing could be better and burns completely.

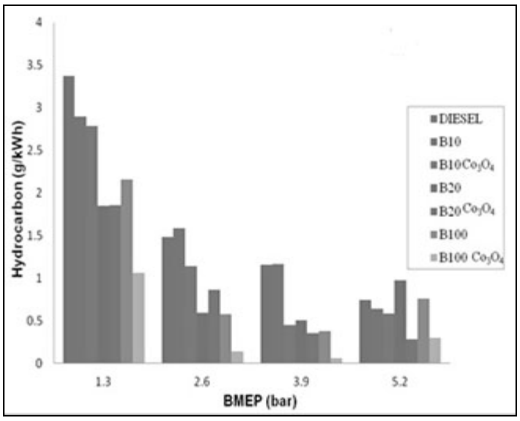

Figure 4: Variation of hydrocarbon with Break Mean Effective Pressure

Sukumar Puhan et al. [1] studied on mahua oil methyl ester as an alternative fuel for diesel engine and found that the engine with methyl ester of mahua oil fielded lower HC, lower CO emission and smoke than conventional diesel at optimum conditions.

Carbon Monoxide

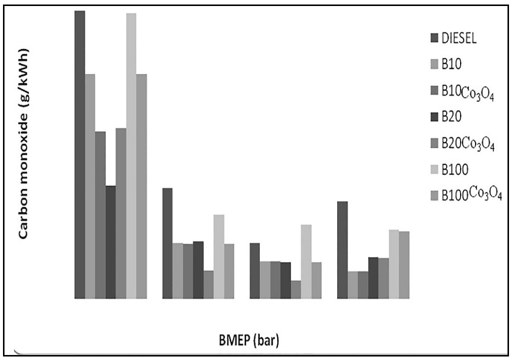

Figure 5: Variation of Carbon Monoxide with Break Mean Effective Pressure

Figure 5 shows the variation in carbon monoxide emission for diesel, biodiesel and its blend. It also shows the effect of additive on CO emission. It is emitted in the exhaust stream, due to lack of oxygen or the engine is running at rich fuel condition when its progression to CO_2 is not completed. At lower loads, biodiesel shows higher CO emission compared to higher loads because biodiesel having higher viscosity, density and molecular weight and hence it is difficult to atomize the biodiesel at low load (low temperature prevails). But at higher loads, biodiesel blends experiences lower CO emission and the reason is cylinder temperature is high, which improves the atomization and air/fuel mixing. This makes it

easier to burn at higher load. Due to the addition of additive, there is marginal reduction in CO emission. At full load condition, B20 added with additive shows ~ 70% reduction in CO emission. This is because the cobalt oxide acts as an oxygen buffer and donates surface lattice oxygen > 1000°C and form stable cobaltous oxide.

$$Co_3O_4 \rightleftarrows 3\,CoO + 1/2\,O_2$$

Gaurav Paul et al. [8] studied the emission characteristics of jatropha biodiesel to mineral diesel and the results showed that the NOx emission is found to increase with load. The experimental study investigated the characteristics of exhaust emissions, and nanoparticle size distribution emitted from diesel engines fueled with 20% biodiesel-diesel blended fuel (BD20) [11]. The emission characteristics of HC, CO, NOx and nano-sized particles were also observed with and without exhaust gas recirculation (EGR) according to engine operating conditions Smoke was decreased. THC and CO emissions of BD20

Nitrogen Oxides (NO_X)

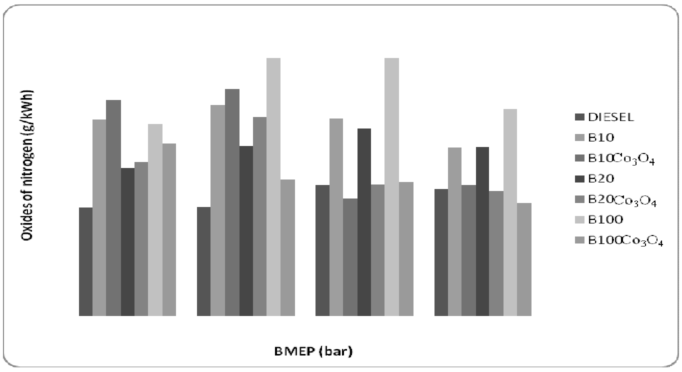

Figure 6: Variation of Nitrogen Oxides (NO_X) with Break Mean Effective Pressure

The variations of NO_X for different blends of biodiesel are compared with diesel and also the effect of additive on oxides of nitrogen emission depicted in Fig 6. The significant factors that cause NOx formation is combustion temperature, injection duration, combustion quality and injection timing.

At lower loads, NOx emission is higher for additive included fuel, because at lower loads, time available for combustion is more and in addition to that the biodiesel possessed oxygen content, which increases the combustion temperature. Injection is advanced by ~ 1° for pure biodiesel is also the reason for NOx emission due to higher value of bulk modulus of cobalt oxide, Significant reduction of NOx at higher loads was observed with the addition of additive. This is due to the metal oxide particles act as a heat sink and carries away the heat content and reduces the cylinder temperature.

CONCLUSIONS

The nanocrystalline cobalt oxide is added as an additive to the jatropha biodiesel. The emission and performance characteristics were studied. Brake specific energy consumption was reduced by the additive addition. Average reductions in BSEC were 7.95% and 2.10% respectively, for B20-Co3O4 and B100-Co3O4 in the full load condition. The results showed that at 75% load condition, B10 shows 1% improvement in thermal efficiency compared to diesel and this is due to oxygen content possessed by the biodiesel, which improves the combustion because resulting of secondary atomization and the complete mixing. The results showed that the emission of NOx was found higher for diesel compared to biodiesel.

Nearly 60% emission reduction was observed for 100% biodiesel at full load, because resulting of secondary atomization and the complete mixing.

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